

Chapter

11

Who Stole the Sun?

In This Chapter

- ◆ How the Moon covers the Sun on a prescribed schedule
- ◆ The diamond ring and other beauties
- ◆ Why the corona looks round or squashed at different times
- ◆ Why you can't see the corona at lesser eclipses

For thousands of years, people have been in awe of the times when the Sun grows thin and all but vanishes in the middle of the day. Mark Twain's *Connecticut Yankee in King Arthur's Court* used the main character's advanced knowledge of such an event to gain the attention and loyalty of a less advanced civilization. (We will say more about him in Chapter 13.) The phenomena that occur at a total eclipse are so beautiful that today's eco-tourists flock in advance to places where the Sun will totally disappear. Disappointingly, though, local officials and journalists may still spread fear, acting as uninformed as the people of 2,000 years ago.

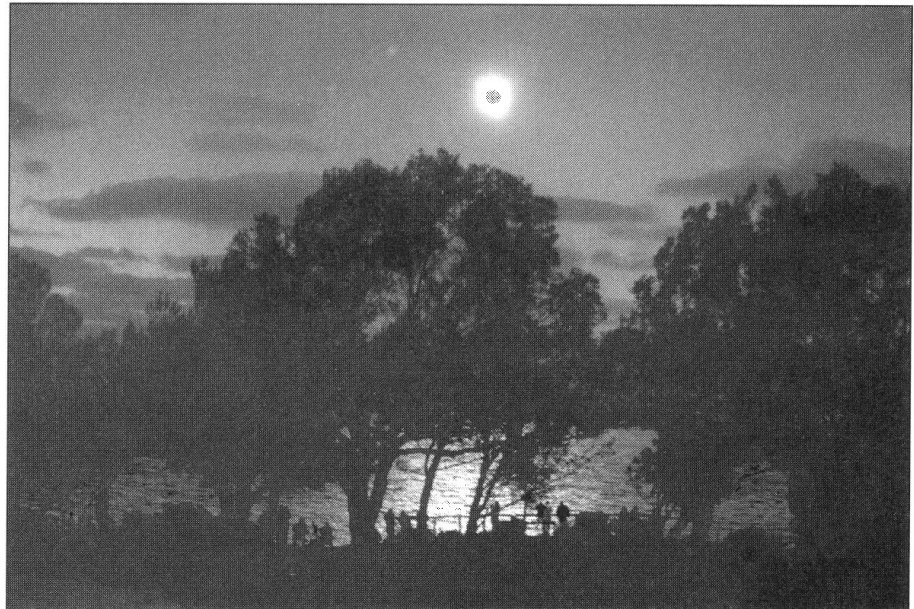
Is It a Dragon Eating the Sun?

For a random place on Earth, you would have to stand around for over 300 years before you found yourself under a total solar eclipse. But solar

eclipses aren't actually very rare: Total eclipses occur about every 18 months somewhere in the world, and a half dozen partial eclipses may also appear in a single year. With modern transportation, you can go to see them all.

The eclipsed Sun in the sky during the total solar eclipse of December 4, 2002, viewed over the ocean at Ceduna, Australia.

(Williams College Expedition)



But what is happening up in the sky when an eclipse occurs? From the ground, it looks as though something is taking a bite out of the Sun. For an hour or so, the Sun gets more and more covered. We now know that the “missing” part of the everyday Sun is actually the silhouette of the Moon.



Sun Safety

Though the Moon gradually covers the everyday Sun for an hour or more before a total eclipse, whenever any of the everyday Sun is visible, it is not safe to look at it directly. So eclipses that are only partial at best, or the partial phases of eclipses that turn out to be total, can be looked at only through special filters or viewed indirectly. We will say more later about safe ways of observing the Sun.

The Sun is about 400 times bigger than the Moon, but it is also about 400 times farther away. As a result, it takes up (scientists say “subtends”) about the same angle in the sky as the Moon. Both take up about half a degree, give or take 10 percent.



The Solar Scoop

Your thumb, viewed at the end of your outstretched arm, subtends about 2° of arc. A full circle is 360° . Your fist, viewed at the end of your outstretched arm, takes up about 10° . You can verify that last point by checking that about nine fists take you from your horizon to the zenith (the overhead point). And you can more than cover the Sun with your thumb—though glare in the sky around the Sun often makes the bright region around the Sun larger than your thumb's apparent width.

Though you can cover the Sun's apparent disk with your thumb, all you see around your thumb is sky. Depending on how pristine and pure the sky above you is, you may see deep blue right up to the edge of your thumb, though you may have to be on a high mountain above a lot of air to see that effect. That is why most solar observatories are on high mountains. From normal altitudes and in common skies, enough dust and haze are present to make the sky brighter in the general direction of the Sun than it is off to the side.



Solar Scribbles

I got a surprising call recently from an advertising agency in Boston. They had seen a 20-year-old picture of me holding up my thumb against the sky, right after my family and I had landed in Hawaii following a flight to see a total solar eclipse over the ocean. You often see solar astronomers in that pose, and I was actually testing the clarity of the sky. However, the advertising agency wanted to use my picture in an advertisement showing someone admiring his thumb because video games are often played with thumbs.

At a total solar eclipse, we see the Sun's corona, which we described in Chapter 1. Why can't we see it any time that the Sun is up, just by sticking out a thumb to block the photosphere, the everyday solar surface? Well, the corona is fainter than the blue sky. So, to see the corona, we need to have the Sun up in the sky—which means that it has to be daytime—but without the blue sky. That is the circumstance of a total solar eclipse.



Solar Scribbles

The Apollo astronauts orbiting the Moon in 1969–1972 could look out and see the solar corona rising ahead of the Sun just before the everyday solar surface peeked out from behind the Moon. More recent robotic spacecraft orbiting the Moon also photographed this effect. But astronauts in Earth orbit don't see the effect because they see the Earth's atmosphere glowing brightly at the edge of the Earth's surface.

The solar corona rising ahead of the Sun, as seen from the Clementine spacecraft around the Moon.

(NASA)



A total solar eclipse, when the Moon entirely blocks the solar photosphere, may last only a fraction of a second or may last as long as $7\frac{1}{2}$ minutes. Only during that period is the solar photosphere entirely blocked. Therefore, only then does the blue sky vanish and the corona, normally hidden behind it, becomes visible.

The partial phases, when the Moon only partly covers the Sun, range from 0 percent to 100 percent coverage. They can last over an hour before the total phase and over an

hour afterward. The Moon can be as much as about 10 percent bigger than the Sun, but once it is covering 100 percent, the eclipse is total. The extra 10 percent goes toward making the eclipse last longer.



Solar Scribblings

What is the tried and true method of getting the Sun back once it begins to disappear in an eclipse? Banging on pots and pans and on drums has been a method used for thousands of years. And it works! Never has the Sun failed to reappear. Of course, it would reappear anyway, but it's fun to make noise.

What should you do when there is a partial solar eclipse in your locality? The easy answer is to look at it, but to look safely by using a projection method or by using a special safe solar filter. Actually, though, partial solar eclipses are pretty boring. Nothing changes rapidly, and even with the sun 75 percent covered, you might not even notice the eclipse if you hadn't read about it in the newspaper (or in this book).

You should find out if totality will be visible somewhere, and do everything you can to get in the band of totality. Only there will you see the beautiful eclipse phenomena.

High Drama in the Sky

The most dramatic aspects of a total solar eclipse are the overall changes around you. When the Sun is half or more covered, you might begin to notice that the shadows on the ground become strangely sharp. That phenomenon occurs because the shadows are being projected from only a crescent-shape Sun, which is narrower in one direction, so the edges of the shadows aren't as fuzzy. As the last few percent of the everyday solar surface is covered, it quickly gets noticeably darker.

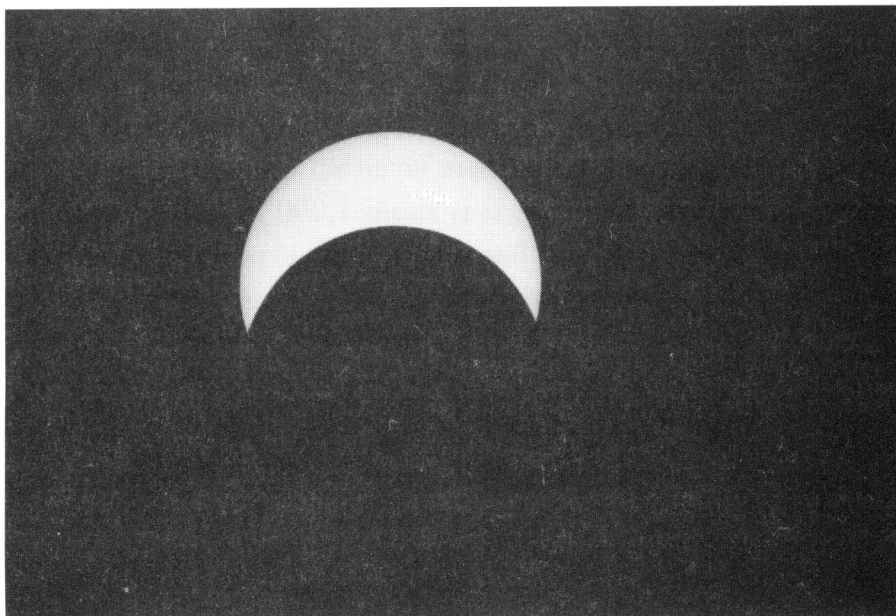


Sun Safety

Even when only 1 percent or so of the Sun is visible, what remains is still too bright to look directly at it safely. Its surface brightness is still that of the everyday Sun, even though its total brightness is reduced. So you must still use your special filters even when 99 percent of the Sun is covered.

Fun Sun Facts

During a total eclipse, the light from the Sun is only one millionth of the strength of the light from the everyday Sun. So even when 99 percent of the everyday Sun is covered, it is still 10,000 times brighter than it is during an eclipse. When 99 percent of the Sun is covered, you are only 0.01 percent of the way toward a total eclipse.



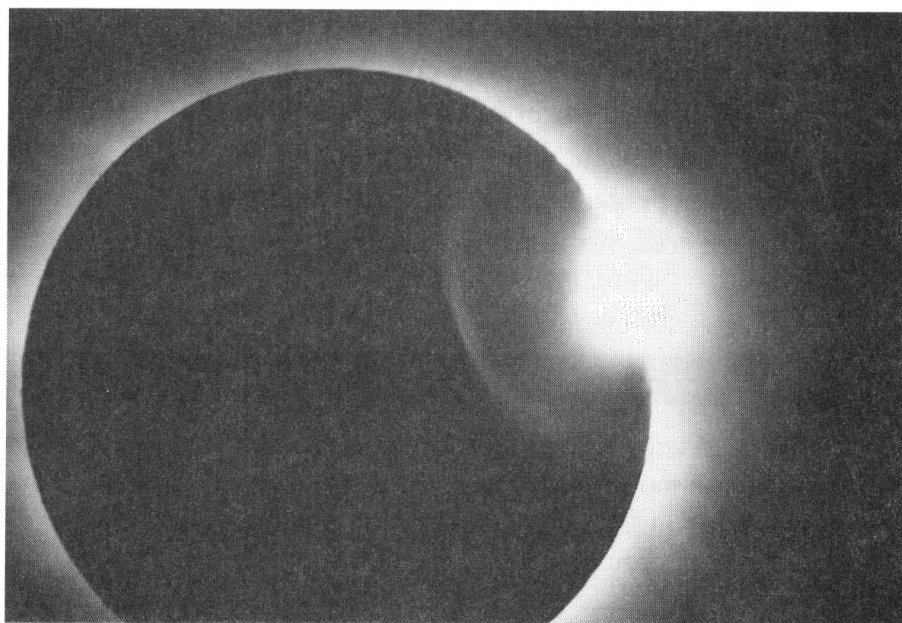
The crescent, partially eclipsed Sun before totality at the eclipse of December 4, 2002.

(Williams College Expedition)

The crescent of the remaining solar photosphere doesn't disappear all at once. First, it seems to break up into a set of bright dots known as Baily's beads. (Baily was a seventeenth-century British astronomer who described the phenomenon.) After all, the Moon's edge isn't perfectly round. Mountains stick up on the Moon, and valleys can be aligned so that a few bits of sunlight shine through them for several seconds. The photospheric light shining through those valleys makes Baily's beads.

The last Baily's bead shines so brightly compared with anything else that is visible that it is called the diamond-ring effect. The "band" of the engagement ring is often the innermost solar corona that has just begun to be visible.

The diamond-ring effect marking the beginning of totality.



Solar Scribblings

I know of at least one bride who received her proposal and engagement ring under the diamond ring in the sky. My wedding present to the couple was a photograph of the diamond ring effect that I took at the same eclipse.

During the diamond-ring's appearance, you might also notice a reddish edge to the Sun to the sides of the diamond. The reddish gas is the solar chromosphere, the intermediate layer between the photosphere and corona. It is about 1,000 times fainter than the photosphere but is still 1,000 times brighter than the corona. *Chromosphere*, of course, simply means "color sphere." As you learned in Chapter 1, it glows reddish largely because hydrogen gas emits especially strongly in that color, and you are seeing hydrogen gas silhouetted against the dark background sky.

As the diamond-ring effect fades, you see the chromosphere better for a few seconds. Then, as it is covered by the advancing Moon, the corona becomes the brightest thing in the sky. Still, it is a million times fainter than the everyday Sun. It is only about the same total brightness as an ordinary full Moon and is equally safe to look at. For however long the eclipse lasts—whether it is a second, as in 2005, or about 7 minutes, as in 2009—you will be able to look directly at the corona and see it in all its glory.

A few reddish prominences, bits of gas that are the same temperature as the chromosphere, are usually visible at the edge of the Sun. There are usually more of them at sunspot maximum than at minimum, but whether you will be lucky enough to have a bright prominence or two at the Sun's edge cannot be predicted long in advance.

What do you see during totality? Up in the sky is a dark circle surrounded by a bright halo. The circle is the silhouetted Moon, and the halo is the solar corona. A detailed look at the corona shows its spiky nature. The spikes are called coronal streamers, which show the shape of the Sun's magnetic field.

During totality, it is quite dark around the Sun, since the blue sky has gone away. You are in the cone of the shadow of the Moon as it falls upon the Earth. But if you look at the horizon in any direction, you are looking outside that shadow cone, and you can see regions where the Sun is shining. Because you are looking through lots of air, only the reddish light comes through to you. Thus, you see a 360° sunset effect all around you. Being outside during this stage is exciting and dramatic. All the beauty and drama is lost when you merely view an eclipse on television or on the Internet.



Solar Scribblings

After every eclipse, you hear stories of someone who forgot to remove the camera's special solar filter during totality. If you try to photograph through or look through the solar filter, you won't see anything at all! The solar corona is too faint to be seen through the filters that are needed for partial phases.

Squashed and Flat

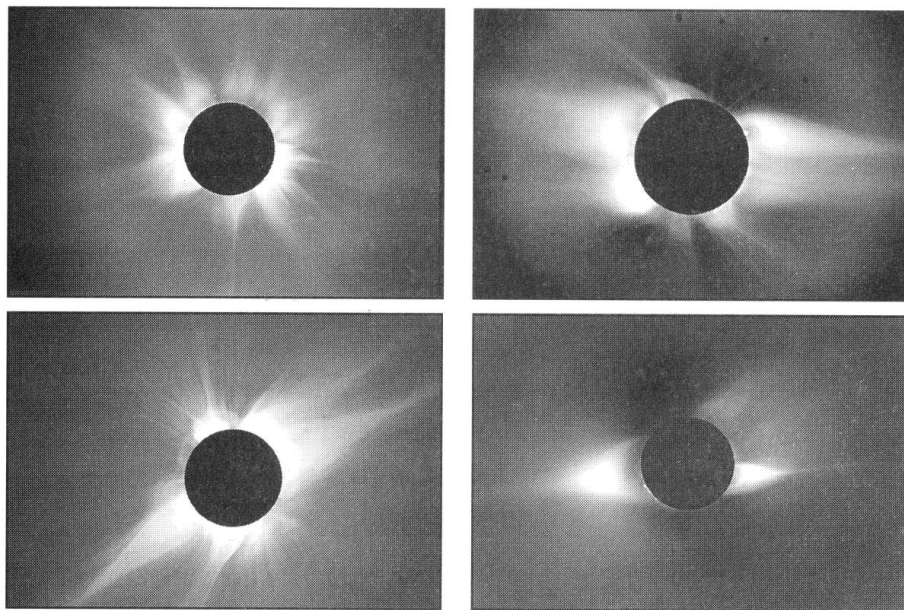
If you were a heart surgeon and were told that you could see inside a human heart, but only if you traveled halfway around the world, and then that you would get only a minute or so to observe it, you surely would go. You would gather lots of colleagues and cameras and do what you could during that minute or so. The case for observing eclipses is similar. You may have to travel to get into the path of totality, but the observations that you can make and the data that you can collect during the brief interval of totality can be studied later. And if a year or two later, you had another opportunity,

you'd go again, wouldn't you? You wouldn't say, "Well, I looked inside a heart last year." You'd be glad for the extra time. The same is true with eclipses. Observing one for a brief interval still leaves lots to do at the next eclipse.

Another reason for observing every possible eclipse is that the Sun changes from day to day and from year to year. The sunspots on the solar photosphere show where tubes of magnetic field leave and re-enter the Sun. They show where the Sun's magnetic field is strongest. The magnetic field extends outward into the corona and holds the coronal gas in place.

The shape of the corona changes with the sunspot cycle. Here are several eclipses photographed with special cameras of the High Altitude Observatory, Colorado, that minimize the bright inner corona to make the coronal shape more apparent.

*(High Altitude Observatory/
National Center for Atmospheric
Research)*



Solar Scribblings

Researchers have been trying for decades to make fusion energy in power plants on Earth. Among the biggest obstacles is the fact that no mechanical wall can withstand the high temperatures. Researchers' best tries use magnetic fields to hold the hot gas in place. In the Sun, magnetic fields hold the very hot coronal gas in place. The lessons we learn from the Sun's constraining those hot gases may lead to an improved understanding of the physical laws that can help us master fusion for peaceful purposes on Earth.

The sunspots, and the magnetic fields all over the Sun, go through an 11-year cycle. The shape of the solar corona, therefore, also goes through an 11-year cycle. During low points of the sunspot cycle, only a few coronal streamers are visible, and they stay mainly near the Sun's equator. But during high points of the sunspot cycle, there are more coronal streamers at high solar latitudes. When projected against the sky, they

seem to stick out in all directions. The overall shape of the corona seen at eclipses then becomes round. So, over an 11-year cycle, the shape of the corona goes from apparently squashed at sunspot minimum, to round at sunspot maximum, and back to squashed again. We had round coronas for the eclipses from 1999 to 2002, and now we will have minimum-type, squashed coronas through perhaps 2007.

The End of Glory

After the seconds or minutes of totality, you may see a brightening and a bit of reddish chromosphere on the solar limb. Then the diamond-ring effect appears again. All too quickly, the sky brightens and the total phase of the eclipse is over.

The partial phases at the end last about as long as the partial phases did leading up to totality. But they are much less well observed and much less photographed. After the glory of totality, the partial phases are anticlimactic.

The Least You Need to Know

- ◆ A total solar eclipse occurs somewhere in the world about every 18 months.
- ◆ The exciting times of a solar eclipse are Baily's beads, the diamond-ring effect, the chromosphere, and the corona sequences.
- ◆ The corona looks round at the maximum of the sunspot cycle and elliptical at sunspot minimum.
- ◆ Only at a total solar eclipse does it get dark enough to see the corona.

